Incremental restoration of a tidally-restricted salt marsh in Cape Cod National Seashore

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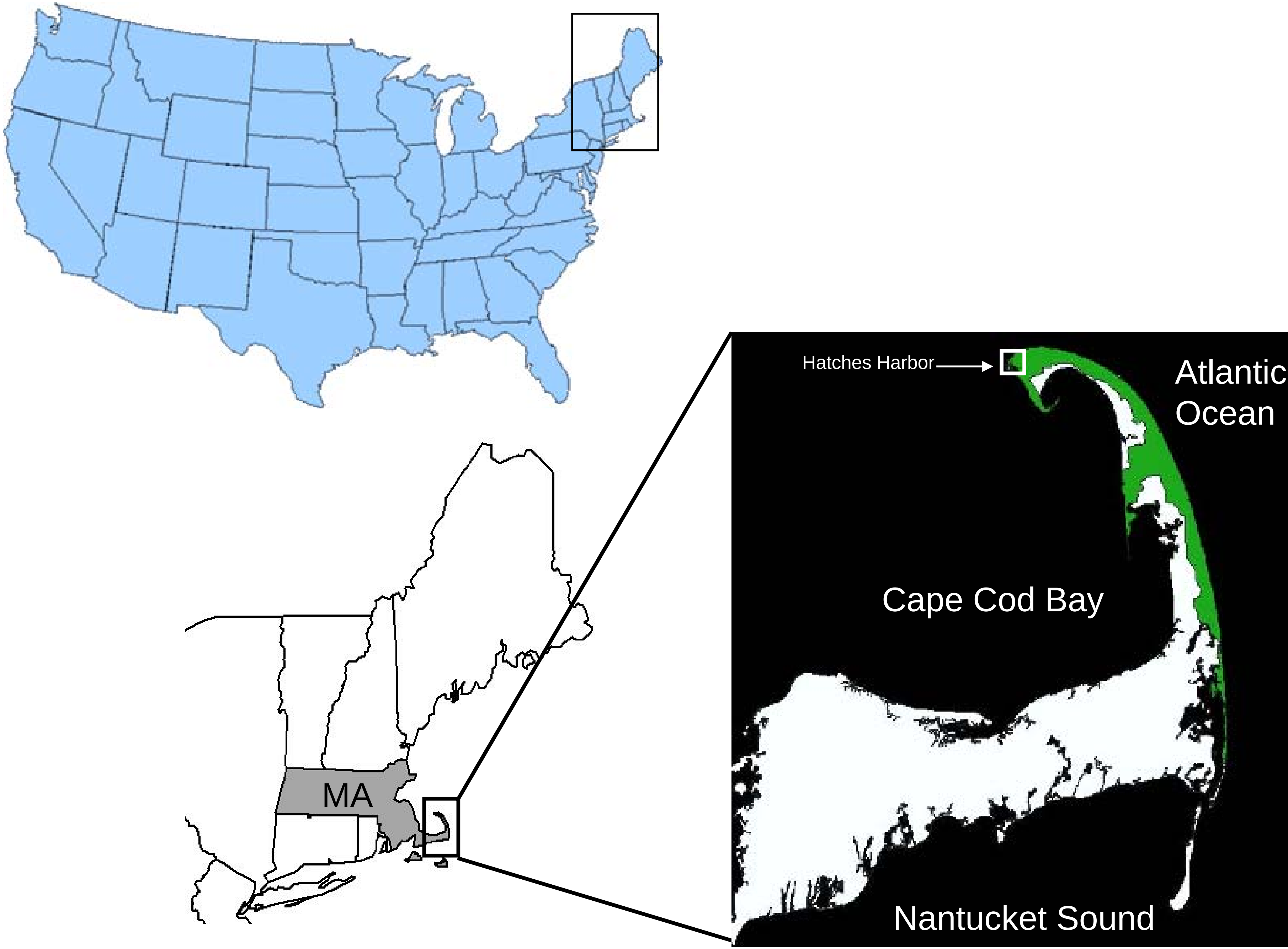


MA
Hatches Harbor
Atlantic Ocean
Cape Cod Bay
Nantucket Sound

Salt marshes are an important resource at CACO

- comprises roughly 10% of the total area of CACO
- the ecological and socio-economic benefits of salt marsh ecosystems to coastal communities are numerous and have been well documented

Consequences….

vegetation

exotic species

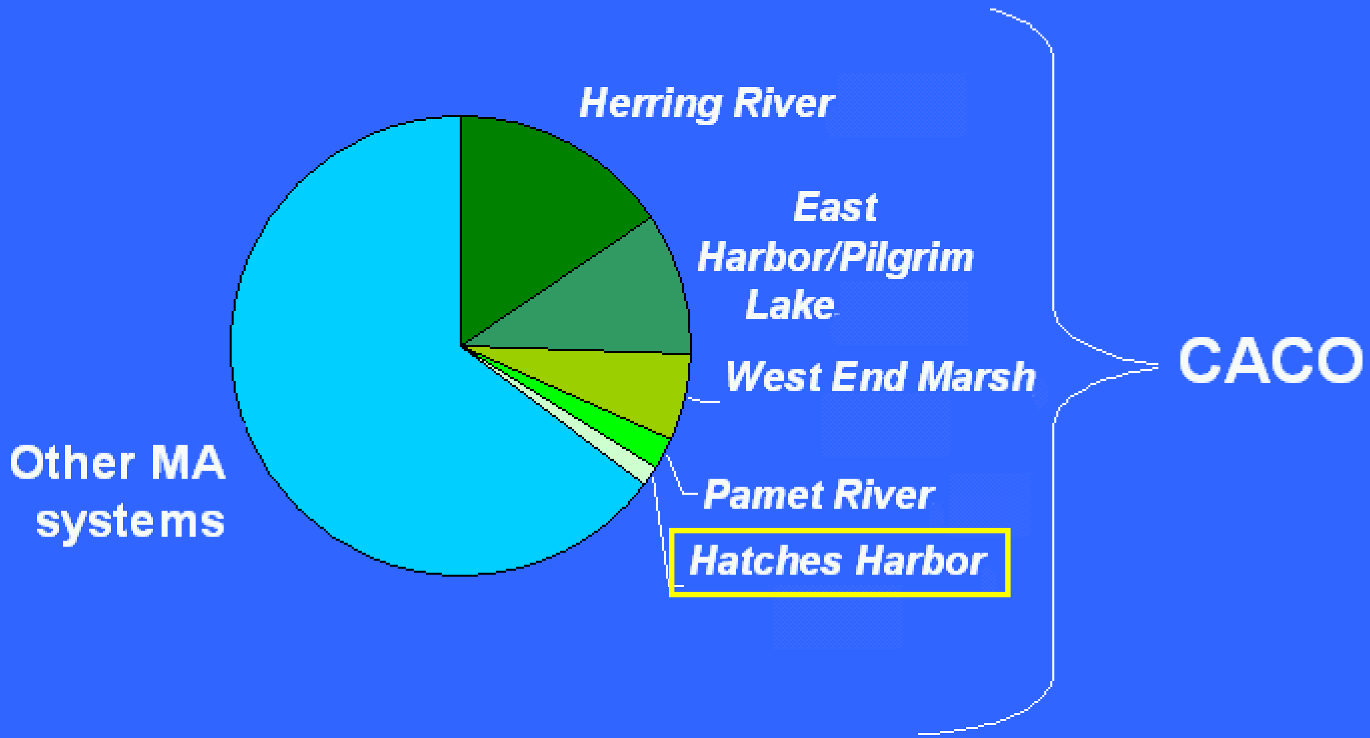
water quality

fauna

Extent and duration of outer Cape Cod tide restrictions:

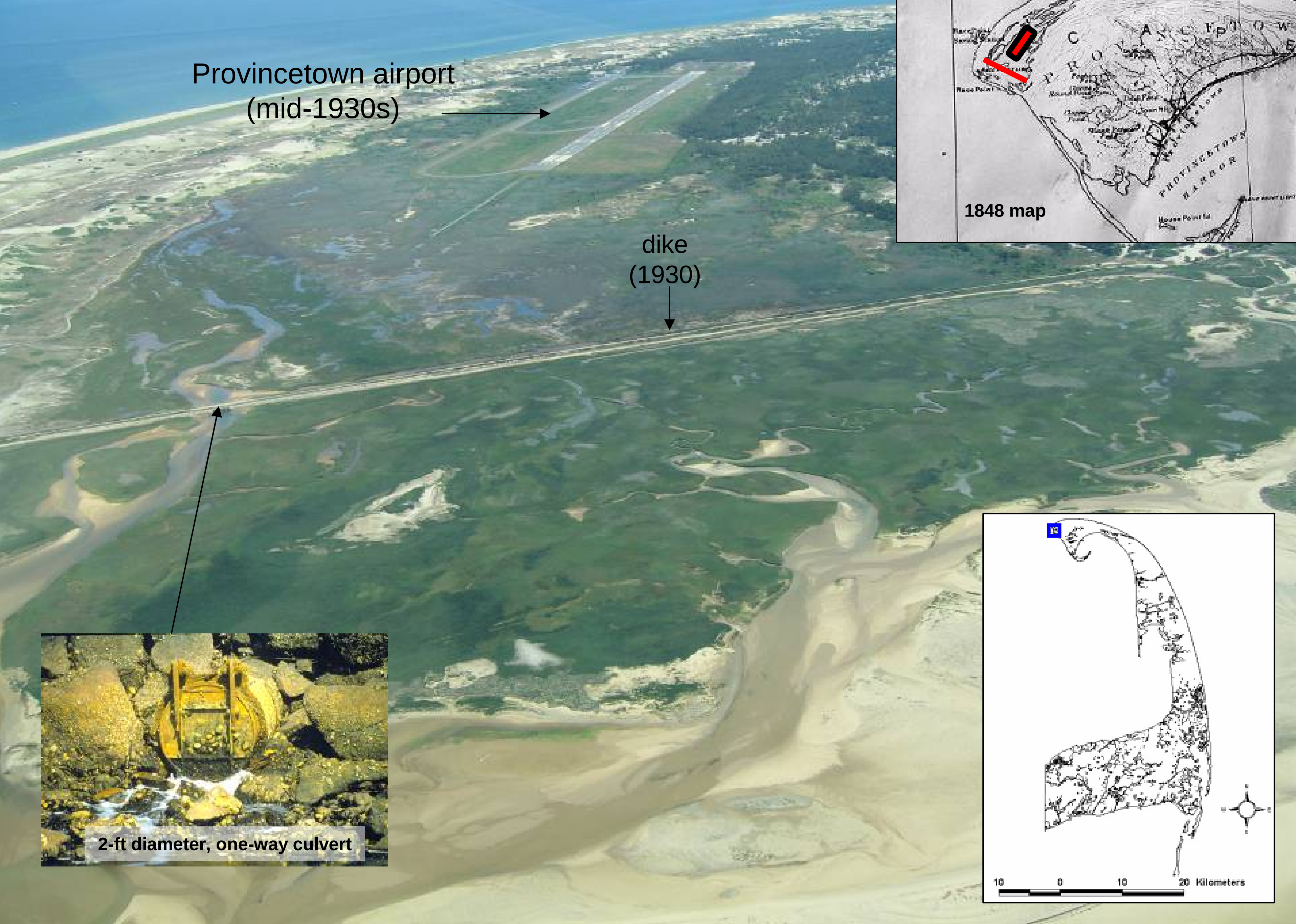
Estuary, township	Acres total	Acres diked	Year of diking
Hatches Harbor, P'town	**420**	**198**	**1930**
West End Marsh, P'town	418	418	1910
East Harbor, Truro	719	719	1868
Pamet River, Truro	388	158	1869
Herring River, Wellfleet	1100	1000+	1909

Massachusetts diked marsh systems (acres)



- Hatches Harbor constitutes a significant portion of dikes marshes within CACO
- CACO has > 1/3 area of the total area of diked marshes within the state

History of Hatches Harbor tidal restriction



Pre-restoration landscape

Unrestricted

DIKE

Restricted

- dominated by *Spartina alterniflora*
- open tidal channels and network of creeks
- full-strength seawater across marsh
- large tidal amplitude

- native veg displaced by shrubs & *Phragmites*
- loss of flow paths through system (creeks lost)
- low salinities or freshwater
- small to no tidal amplitude

1986 – proposal by CACO and Mass CZM to ease restriction

<u>Objectives</u>

- Restore tide range and salinity to the extent possible
- Re-establish salt marsh communities
- Eliminate exotic species (e.g., *Phragmites*)

* Maintain flood protection for municipal airport (Instrument landing system)

1987 – hydrologic model constructed (Garvine) for various culvert designs

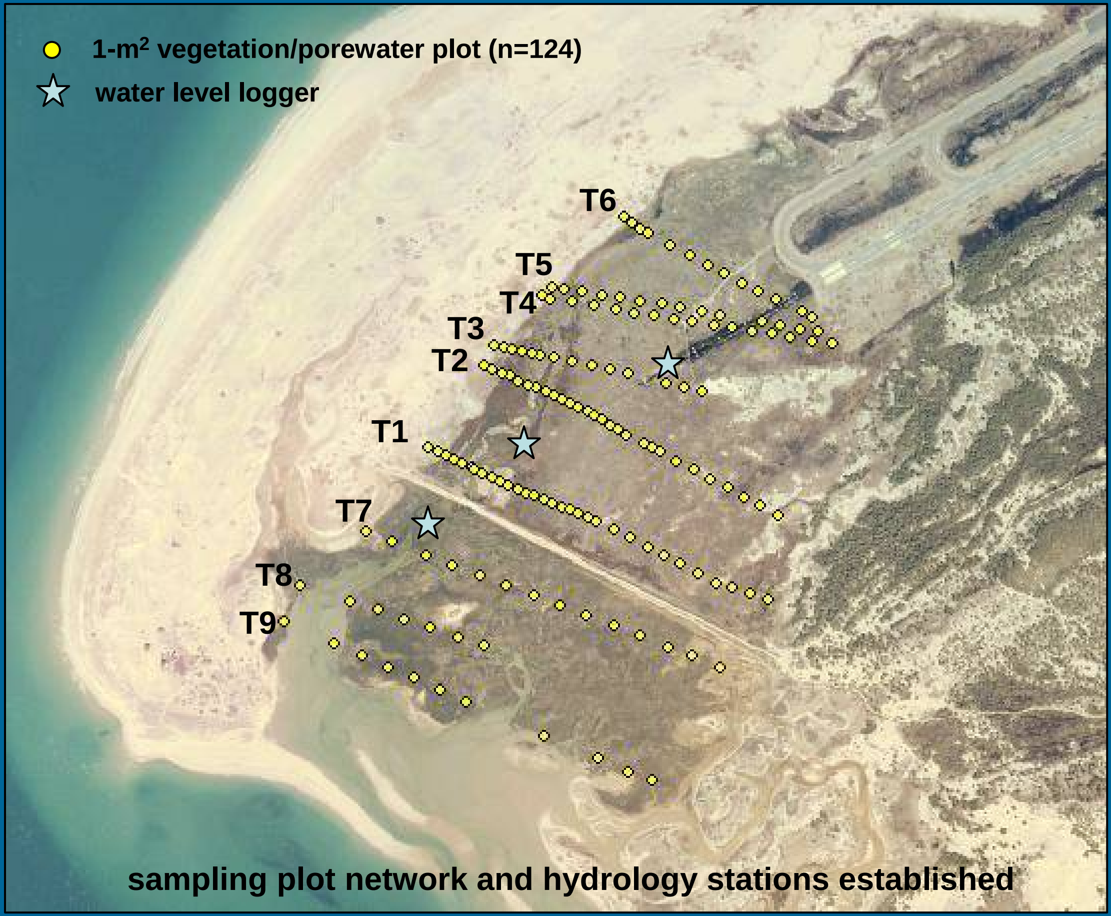
(data in feet relative to MLW)

Culvert ht (ft)	Mean High	Mean Low	Mean Range	Spring high	Storm high
Two culverts					
0.5	8.35	7.40	0.95	8.49	9.83
1.0	8.42	7.37	1.05	8.68	10.29
Four culverts					
0.5	8.55	7.31	1.24	8.81	10.06
1.0	8.68	7.31	1.37	8.91	10.55
1.5	8.68	7.31	1.37	8.98	10.85
2.0	8.72	7.31	1.41	8.98	11.04
2.5	8.72	7.31	1.41	9.01	11.14
3.0	8.72	7.31	1.41	9.01	11.24

* Airport threshold = 10 ft-MLW

- model predicts tides just upstream of culverts (in reality there is dampening)
- gates could be lowered in anticipation of a large storm

1997 - Agreement between CACO and P'town for incremental restoration
- Agreement called for careful monitoring of restoration process



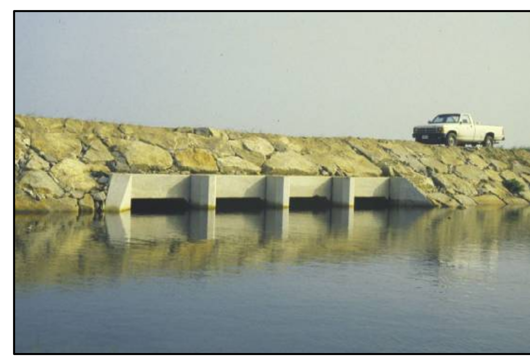
Monitoring design put together by Roman et al.

1998 - Large, adjustable (gated) culverts installed into dike

A summary of increases in mean tidal range in the diked marsh with incremental culvert opening, 1998 - 2007.

Years	Number of open culverts	Dimensions of opening	Opening area (m^2)
Pre-1999	1	2-ft ID old circular culvert	$\boxed{0.29}$
Mar 1999 – Mar 2000	2	2.13 m wide X 0.10 m high	0.42
Mar 2000 – Mar 2001	4	2.13 m wide X 0.10 m high	0.85
Mar 2001- Oct 2003	4	2.13 m wide X 0.40 m high	3.41
Oct 2003 – Jun 2005	4	2.13 m wide X 0.70 m high	5.96
Jun 2005 onward	4	2.13 m wide X 0.90 m high	$\boxed{7.79}$

> 25X



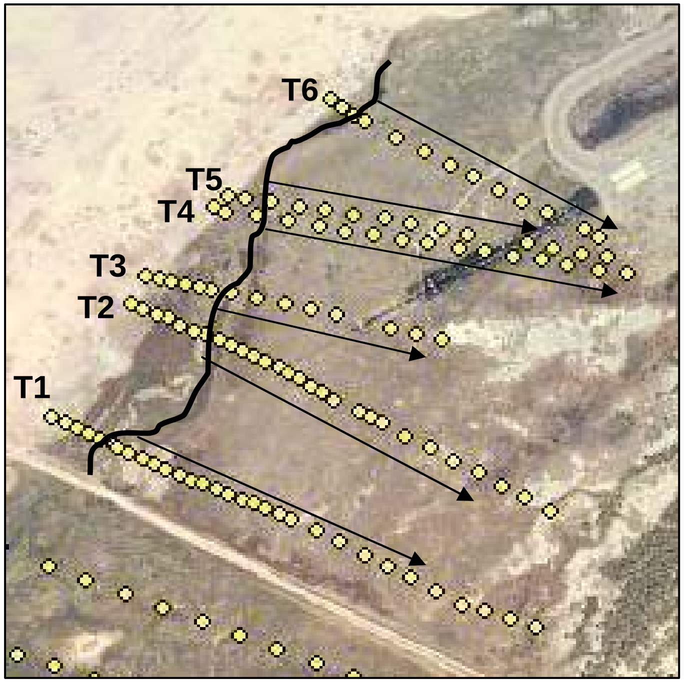
data in m (NAVD 88)

	Mean High	Mean Low	Tidal Range	Area of opening	% tidal range of unrestricted marsh
Unrestricted					
11/16/98 - 12/22/98	1.42	0.76	0.66		
09/12/02 - 10/02/02	1.72	0.83	0.88		
09/12/06 - 10/02/06	1.71	0.81	0.90		
Restricted					
11/16/98 - 12/22/98	1.29	1.04	0.26	0.29	39%
09/12/02 - 10/02/02	1.60	1.04	0.56	3.41	63%
09/12/06 - 10/02/06	1.59	1.04	0.55 (0.43)	7.79	61%

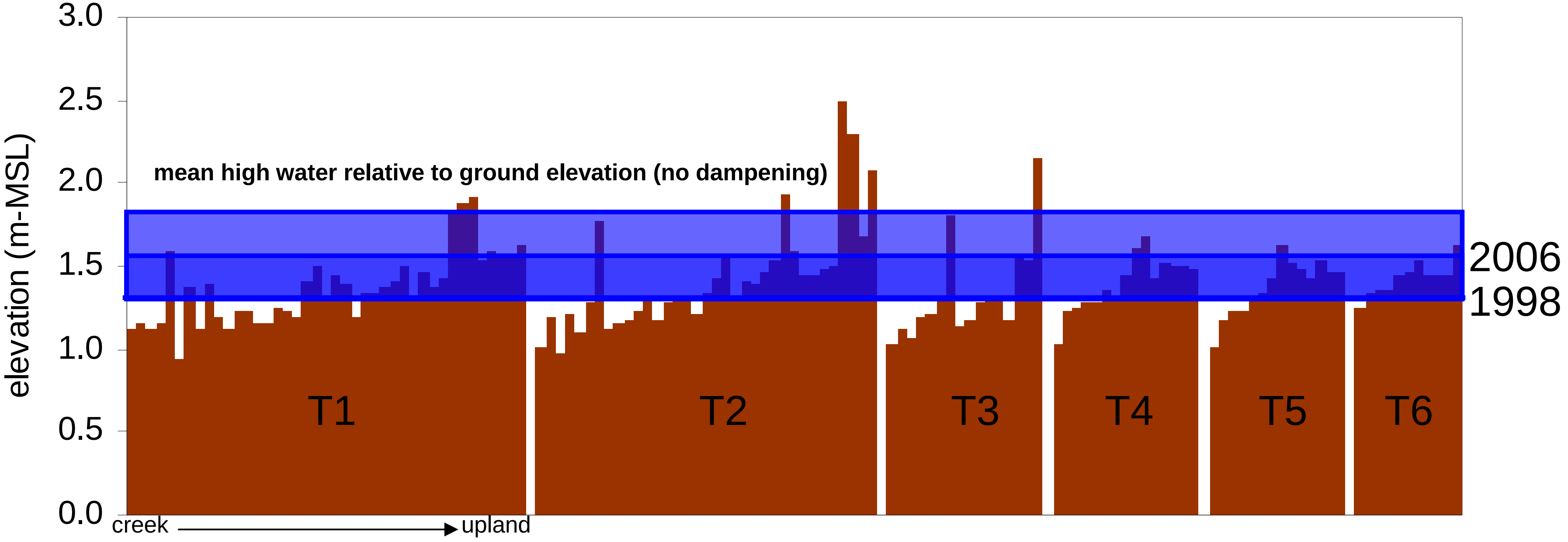
(0.43) model estimate

• year to year comparisons within same side of marsh confounded by deployment during different seasons and changes in geomorphology of tidal inlet

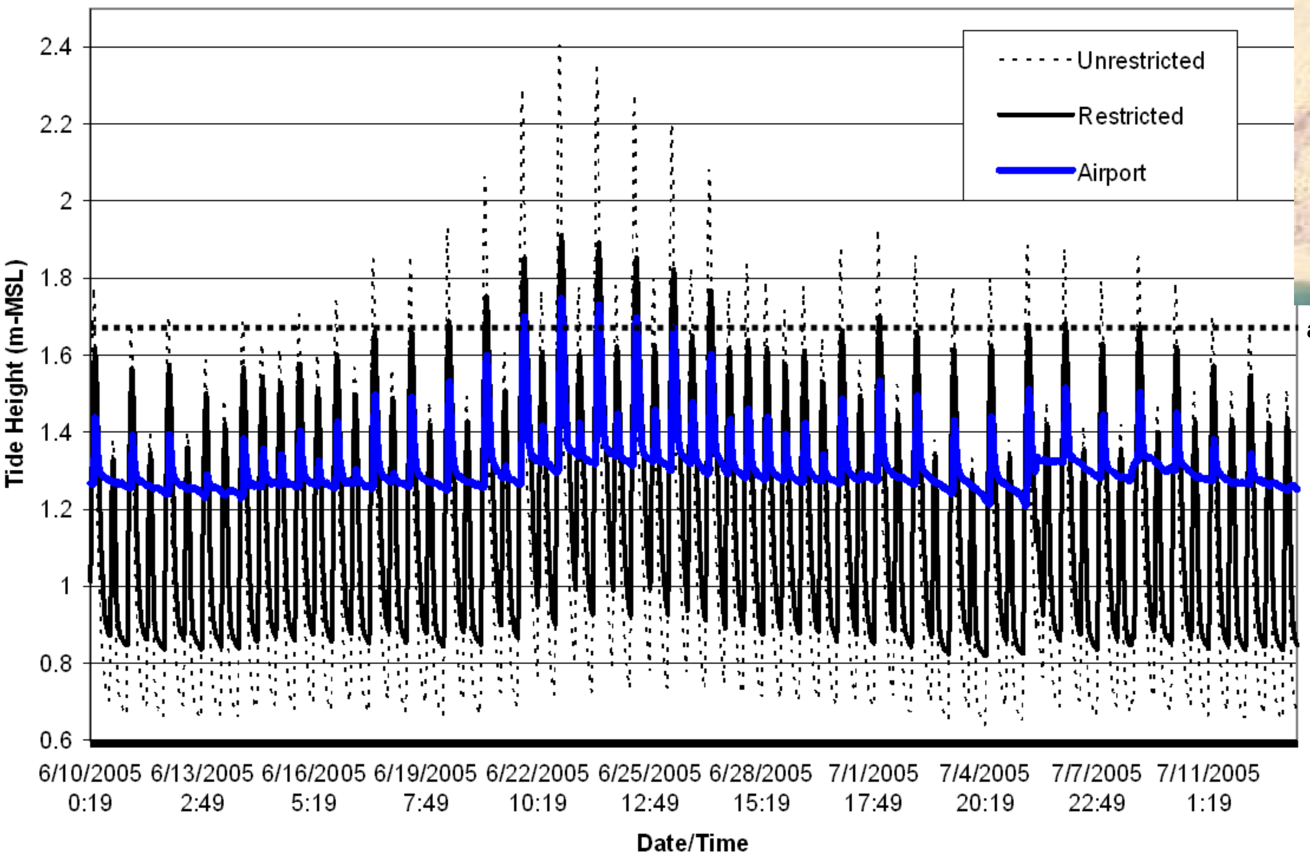
• restricted to unrestricted comparisons are valid since deployments were concurrent every year



22% increase translates to a much larger area of marsh flooded by tides

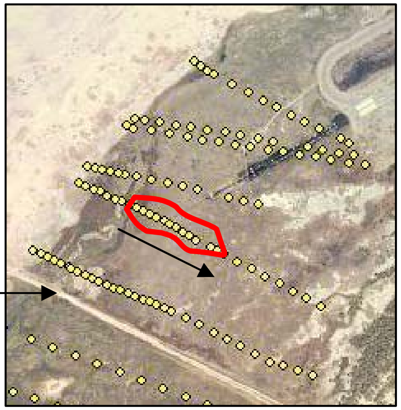


Tides (continued..)

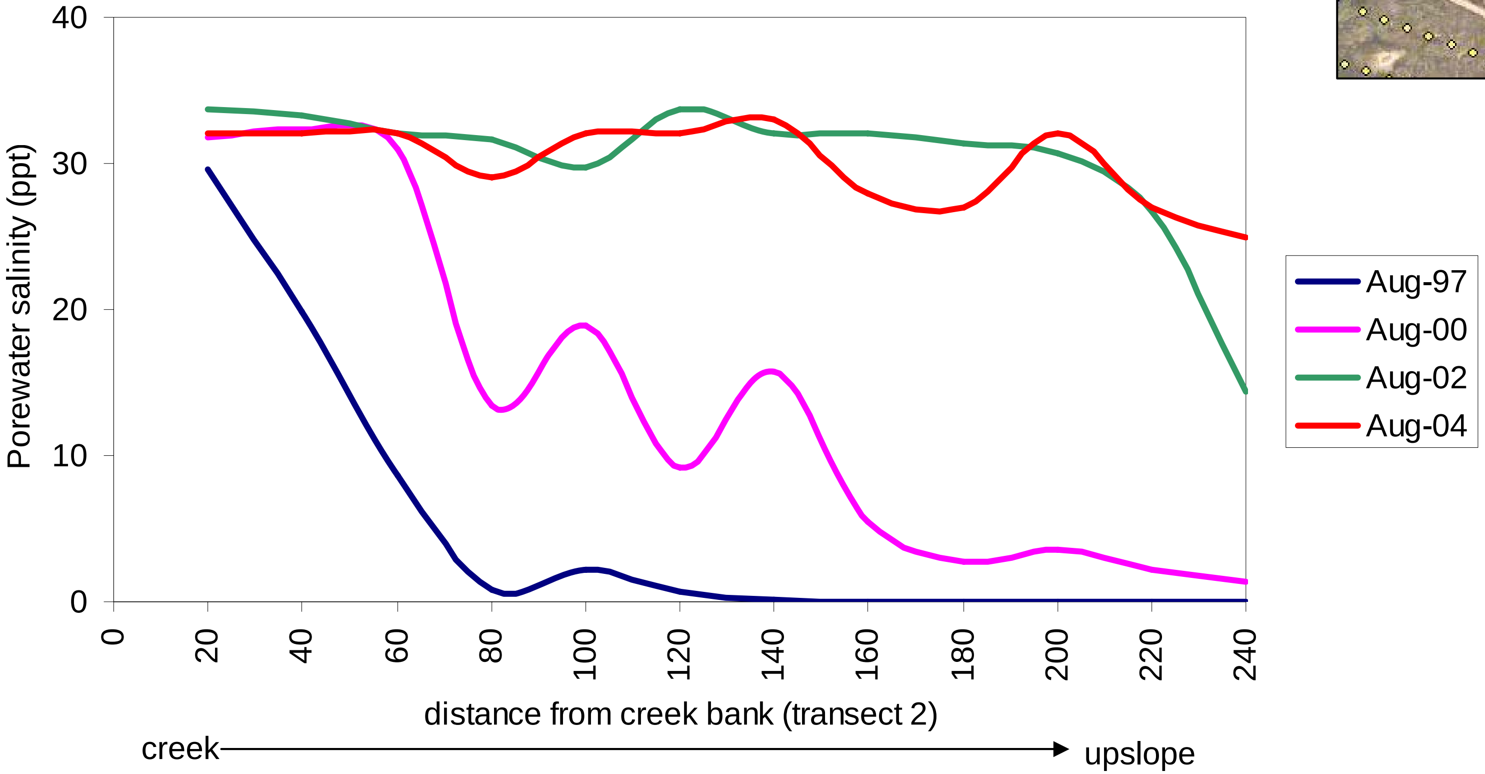


* dike still dampens high tides enough to protect airport (with berm construction)

Porewater salinity

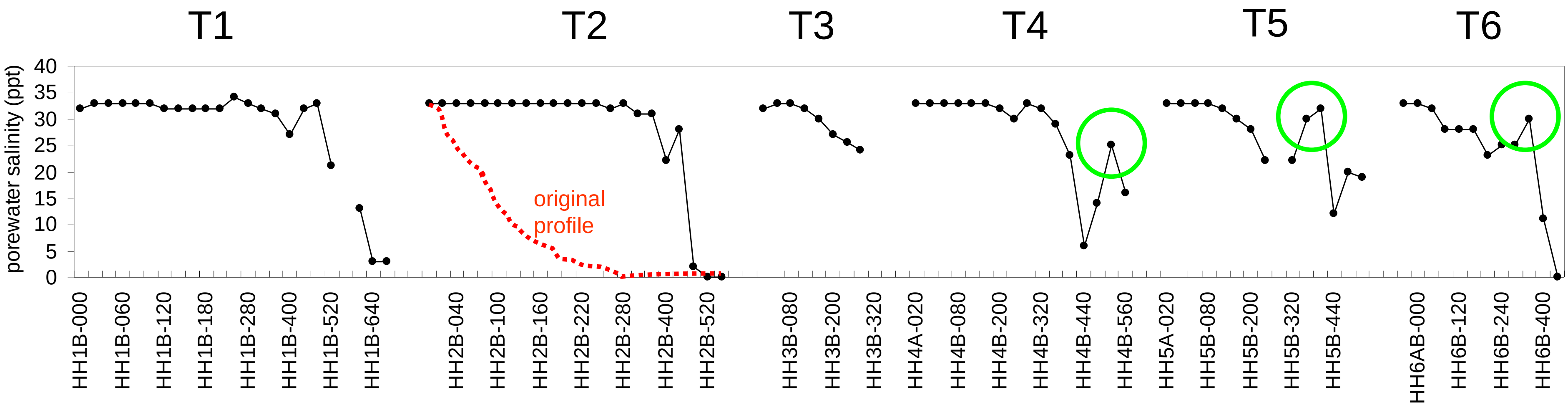


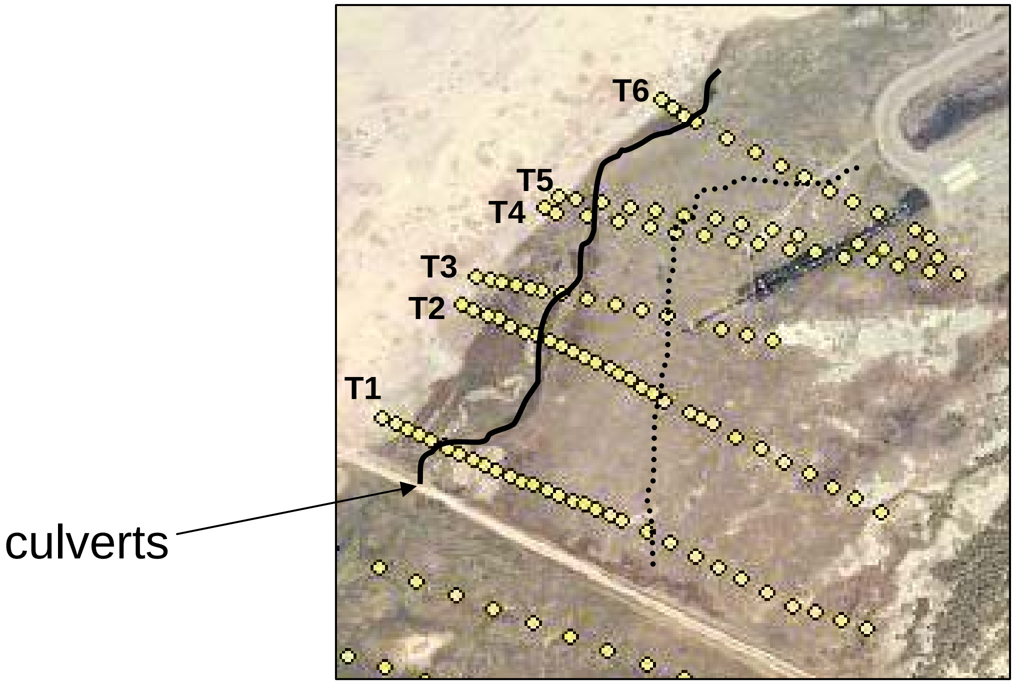
culverts



* sulfides are extremely low (<0.05 mM) to undetectable

Porewater salinity 2007

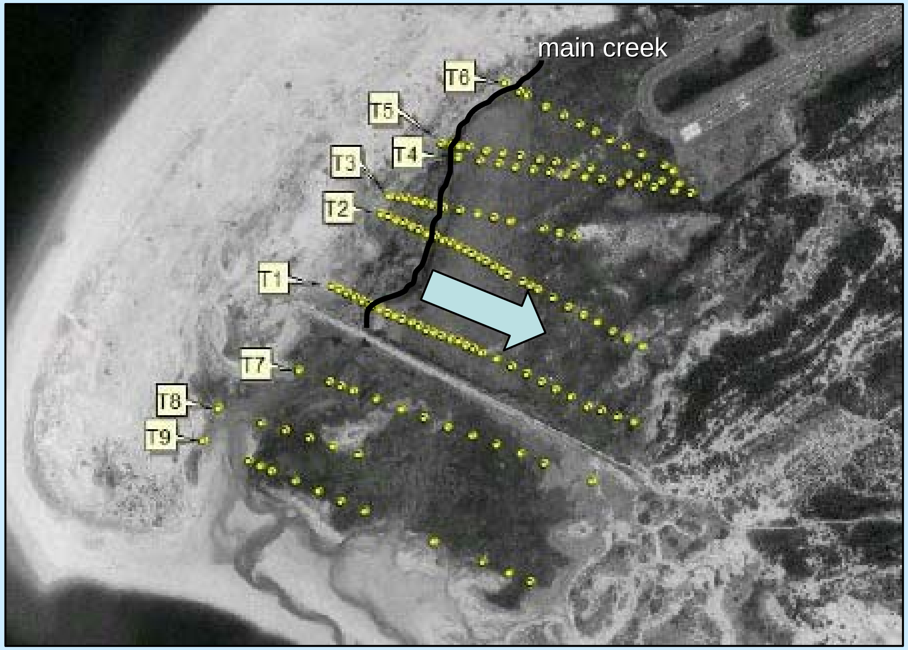


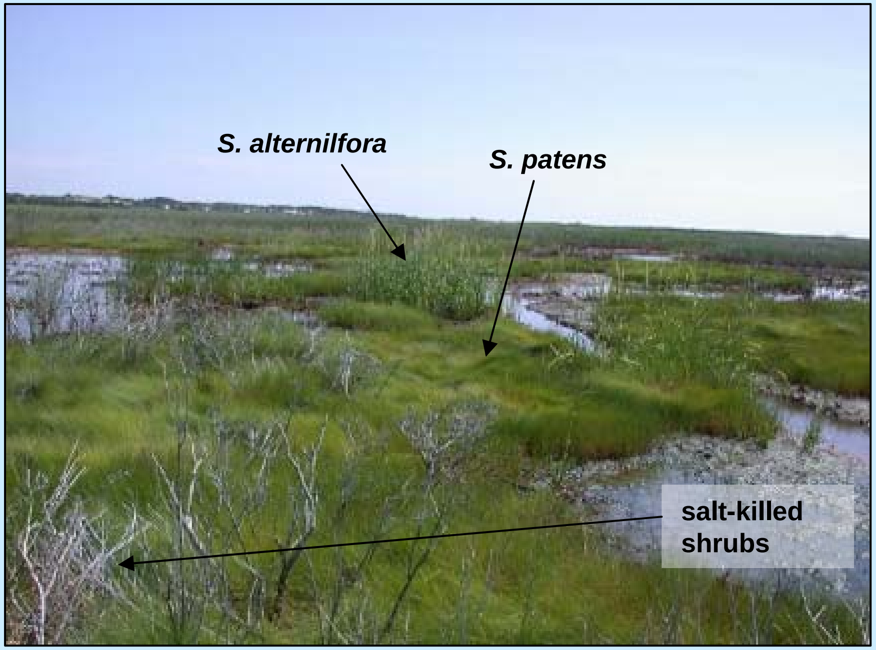


Vegetation: new wetland area created in what became dune communities after restriction

Native halophytes

Species	Parameter	Transect	1997	2002	2004	2006
S. alterniflora	Frequency	1-6	0.097	0.107	0.165	0.311
	Distribution	1	0	0	140	260
		2	0	0	40	60
		3	0	0	40	80
		4	0	0	80	80
		5	0	0	40	80
		6	0	0	0	0
S. patens	Frequency	1-6	0.146	0.136	0.194	0.165
	Distribution	1	40	60	60	60
		2	0	20	60	80
		3	0	0	80	80
		4	160	160	240	240
		5	200	200	240	240
		6	0	40	40	40



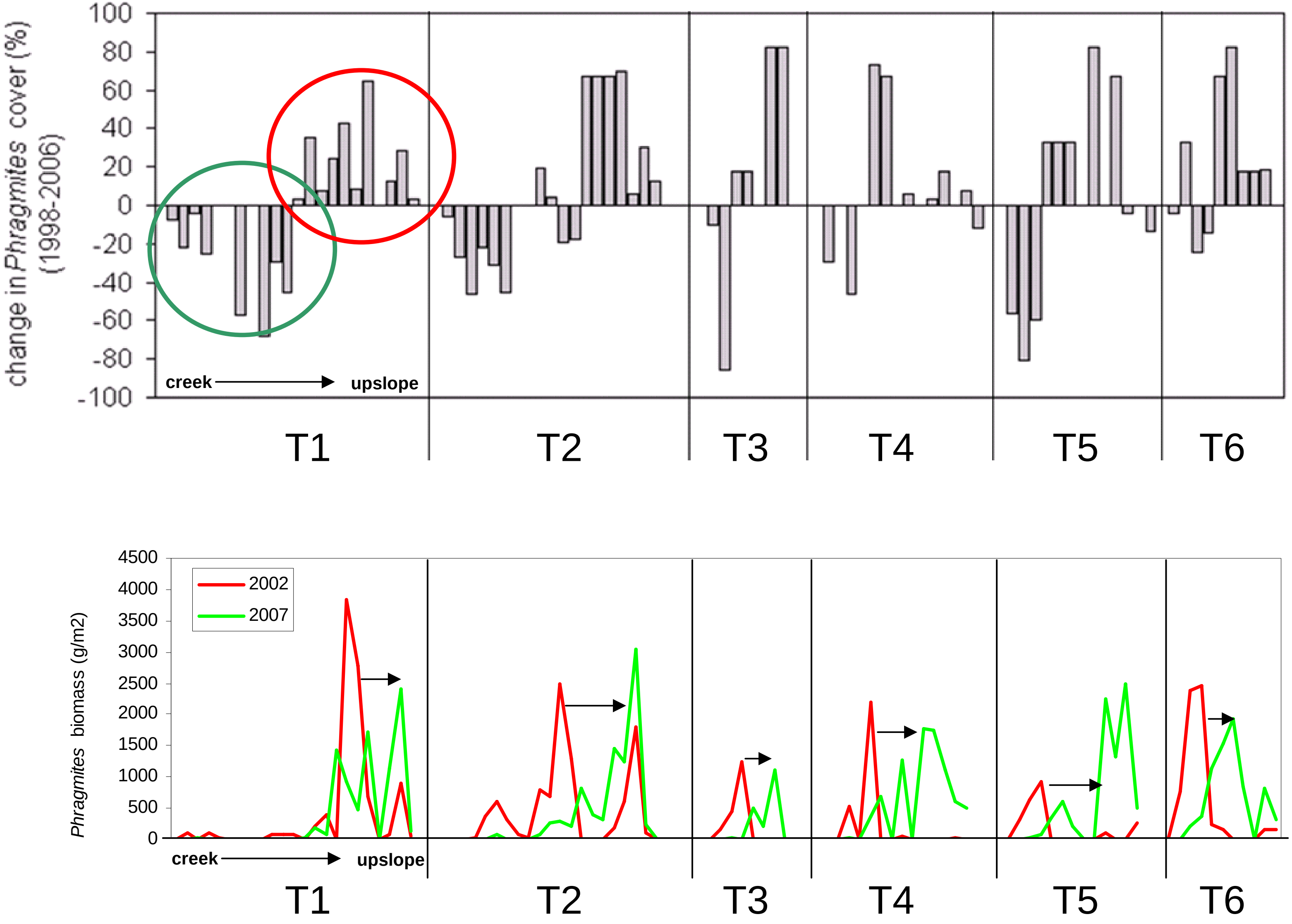


Exotic species

Phragmites australis (invasive haplotype)

	1997	2002	2004	2006
no. plots with *Phragmites*	47	52	58	58
Phragmites biomass	ns	597 (117)	558 (98)	808 (119)
Phragmites cover	243	238	282	287

Phragmites upslope migration



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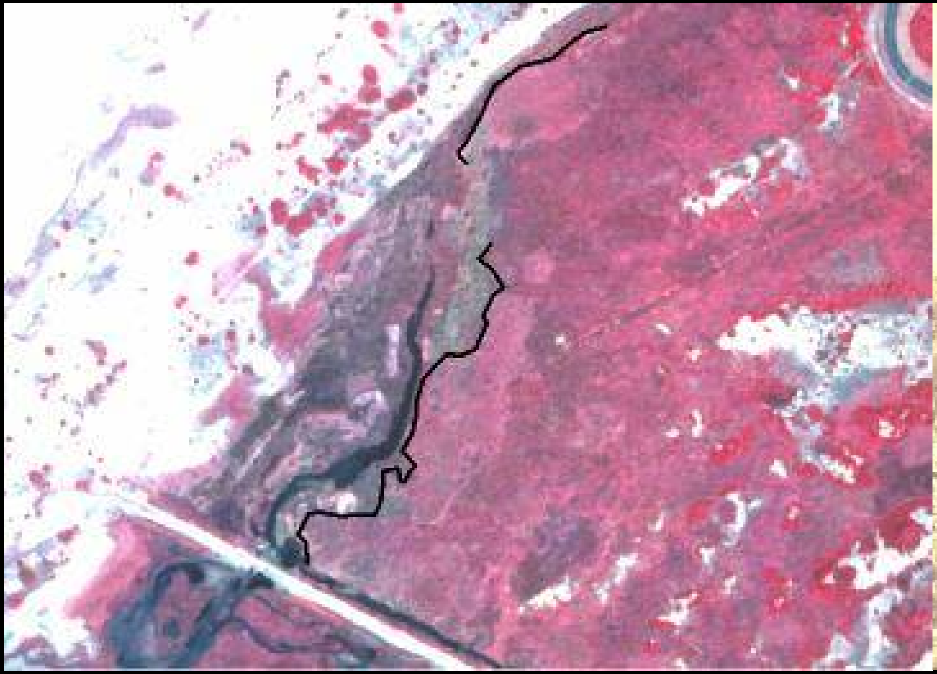

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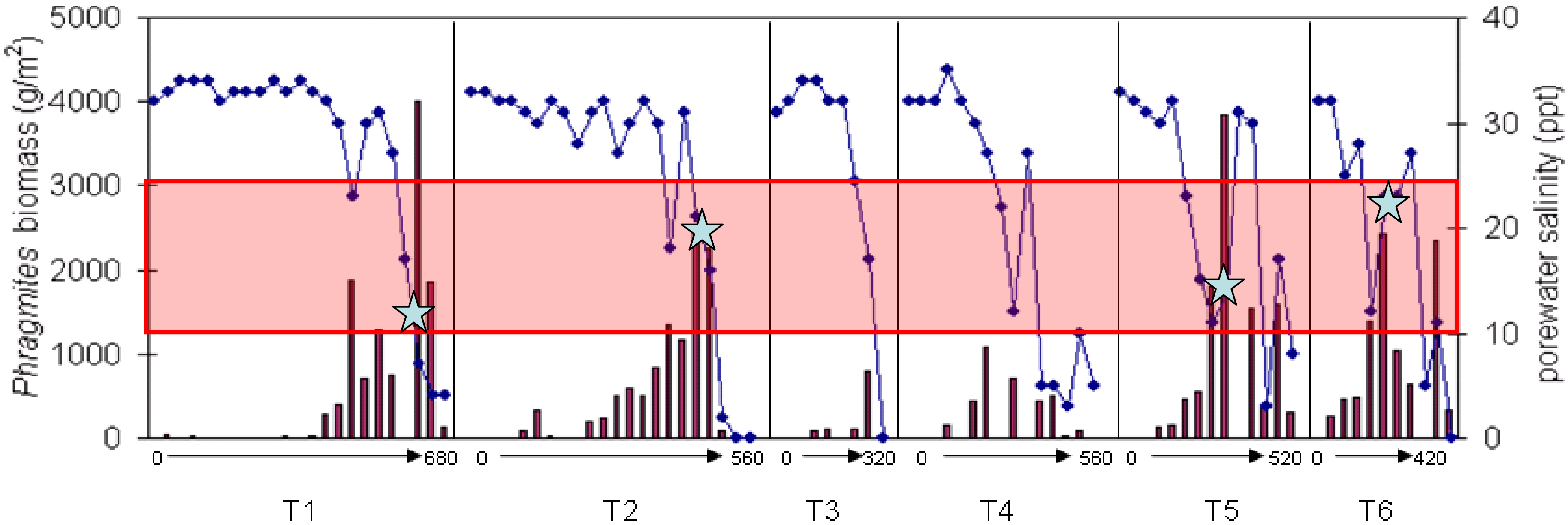
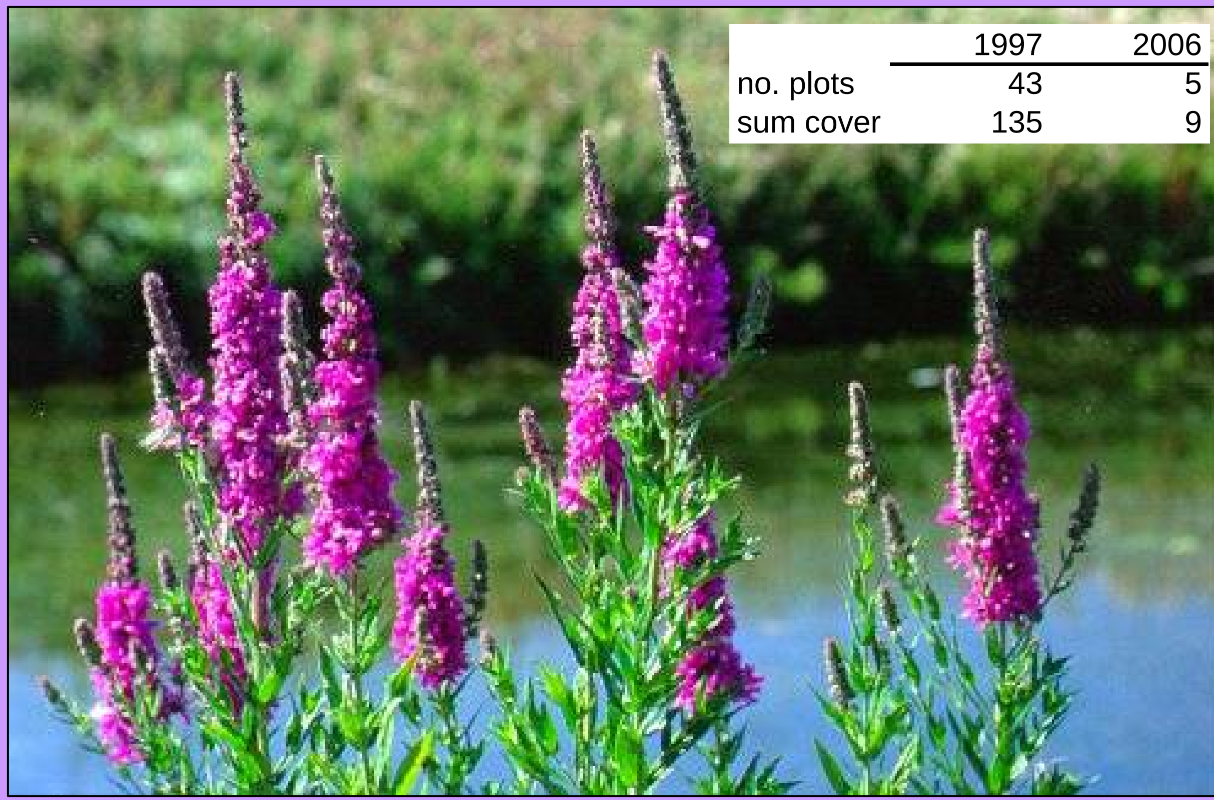
As the ~10-25 ppt salinity niche moves upslope, *Phragmites* follows



Lythrum salicaria (purple loosestrife)



	1997	2006
no. plots	43	5
sum cover	135	9

The restricted-side community has changed significantly with each incremental opening, but in its entirety is still very different from the unrestricted marsh

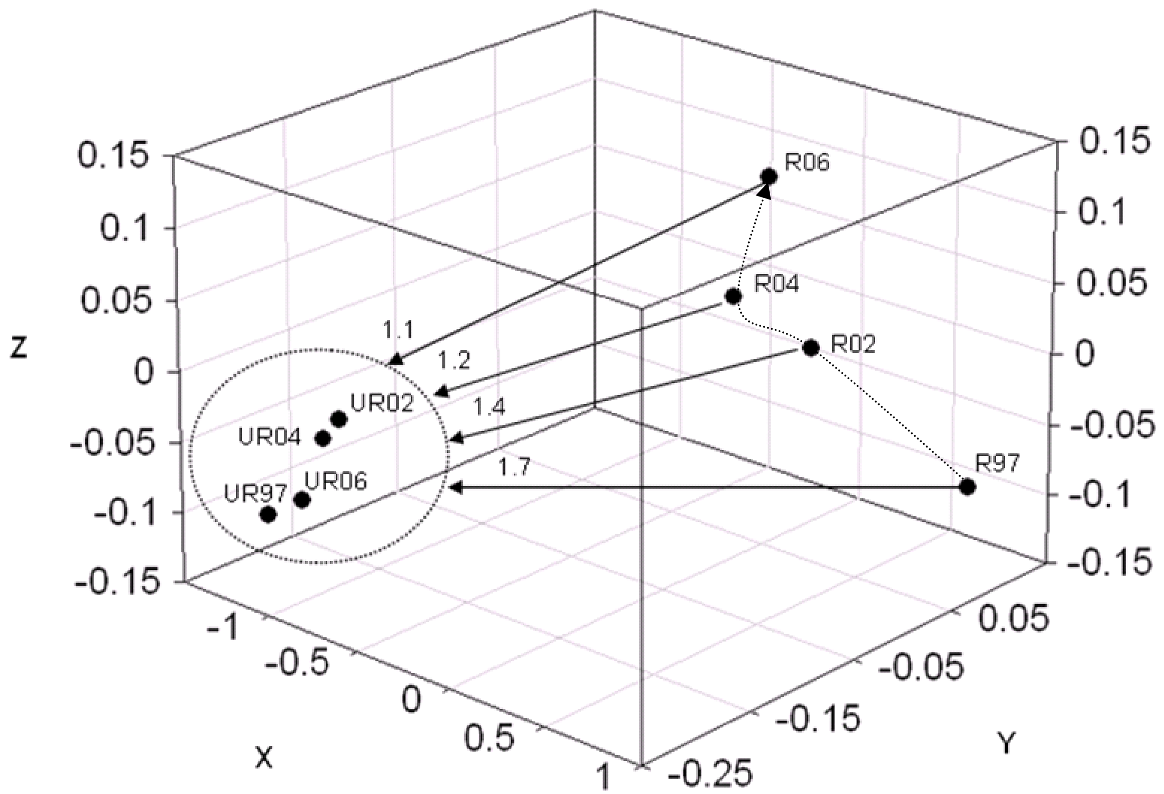
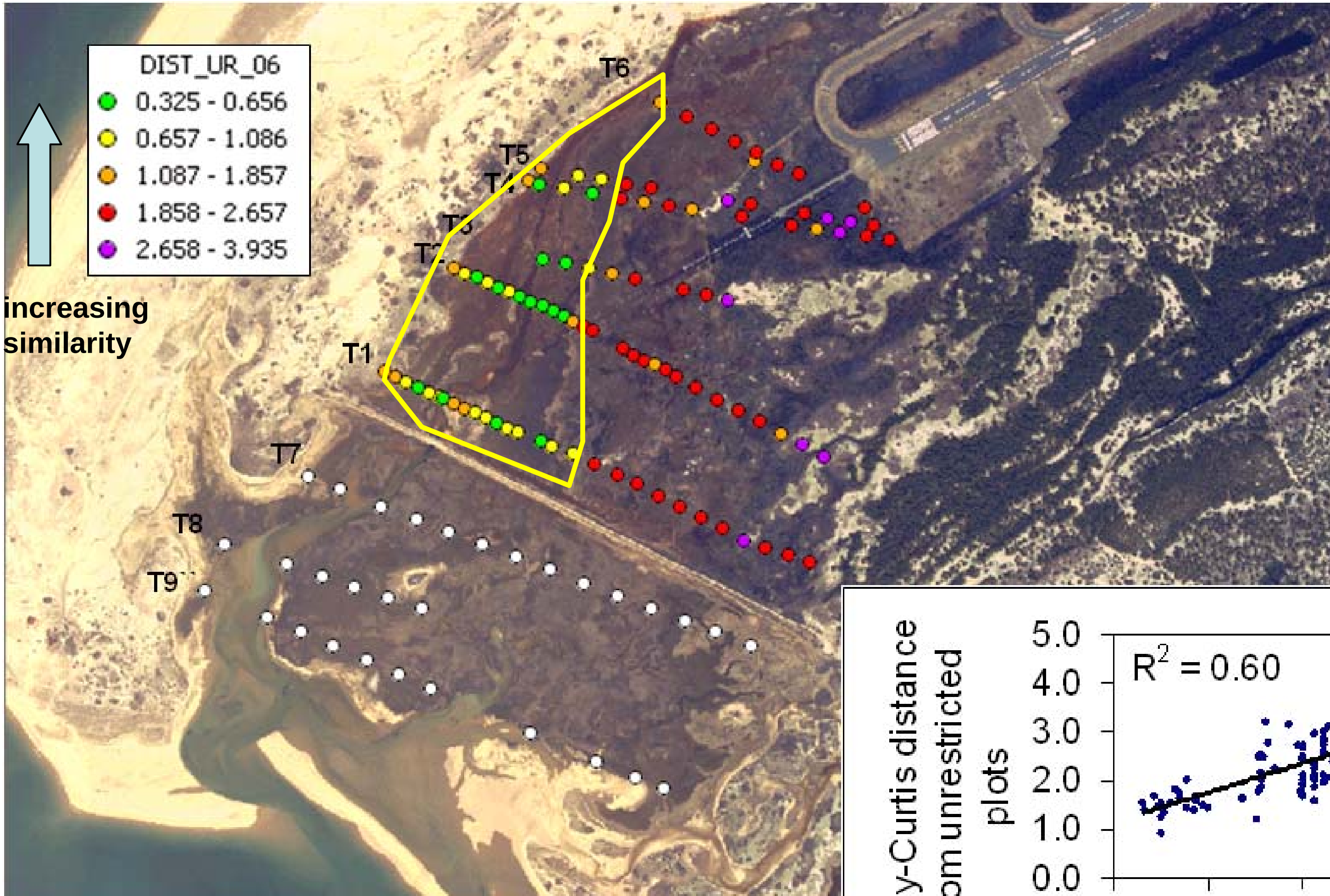
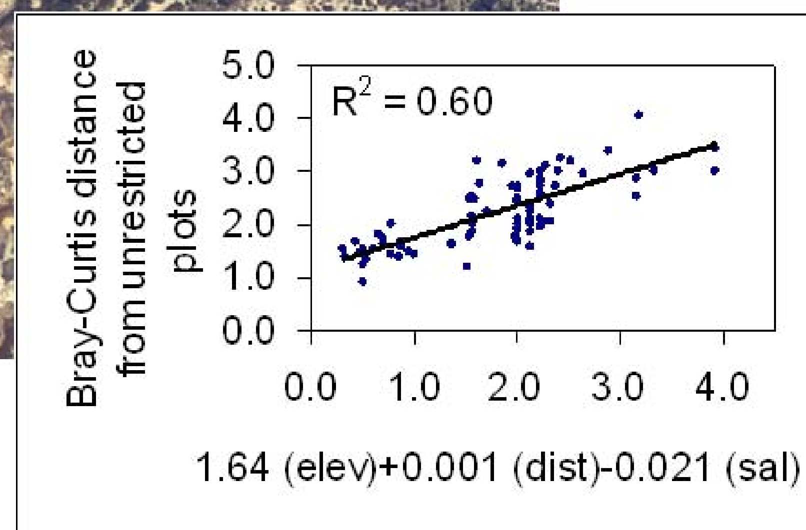


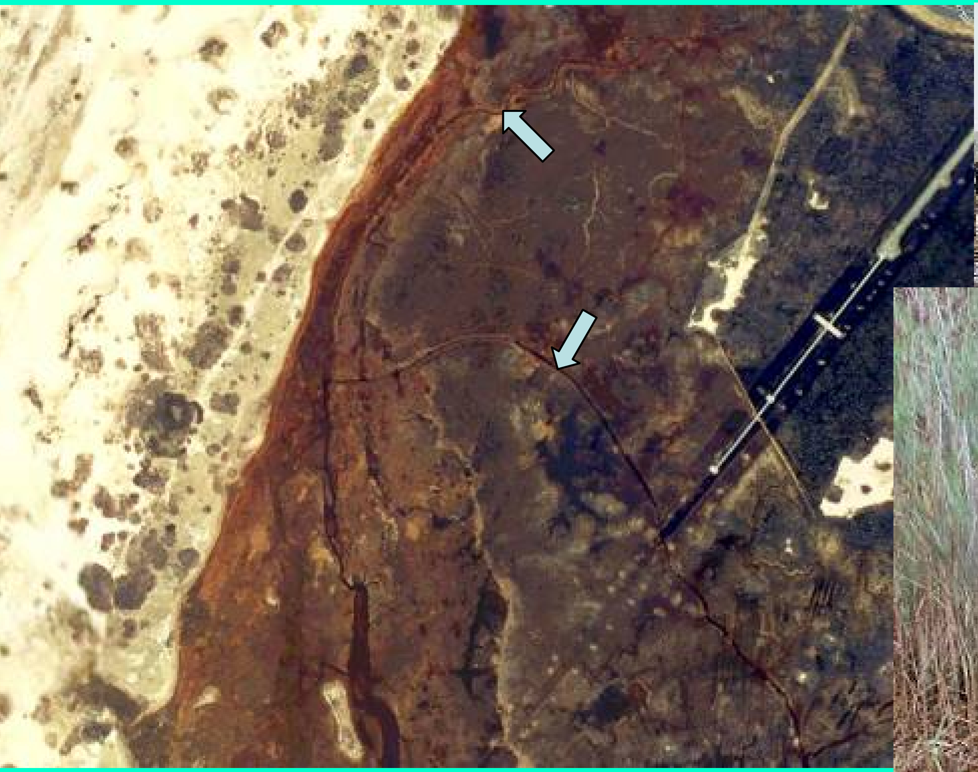
Figure 3. Three dimensional graph of mean Bray-Curtis values in the tide-unrestricted vs. -restricted marsh areas in 1997, 2002, 2004, and 2006. Points more similar to each other in community composition appear closer together (R = restricted marsh, UR = unrestricted marsh, numbers beside labels denote last two digits of the year). Numbers above the arrows indicate the differences between mean Bray-Curtis similarity values of tide-restricted plots (each year) and tide-unrestricted plots (all years pooled).

Species changes since 1998 – spatial heterogeneity

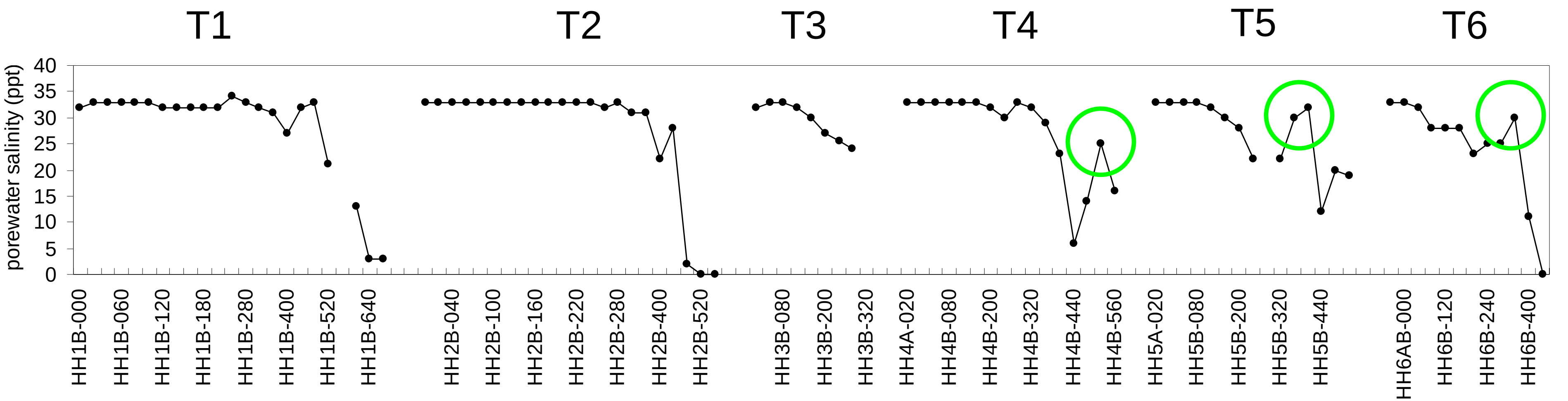




Accelerating salt marsh restoration through active management
- re-creating tidal creeks (2004)

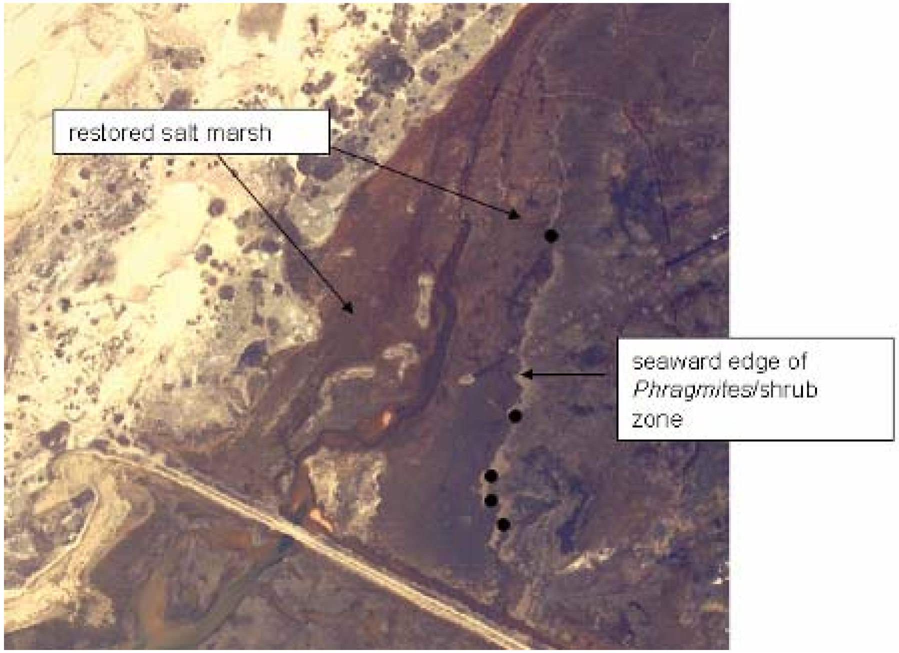


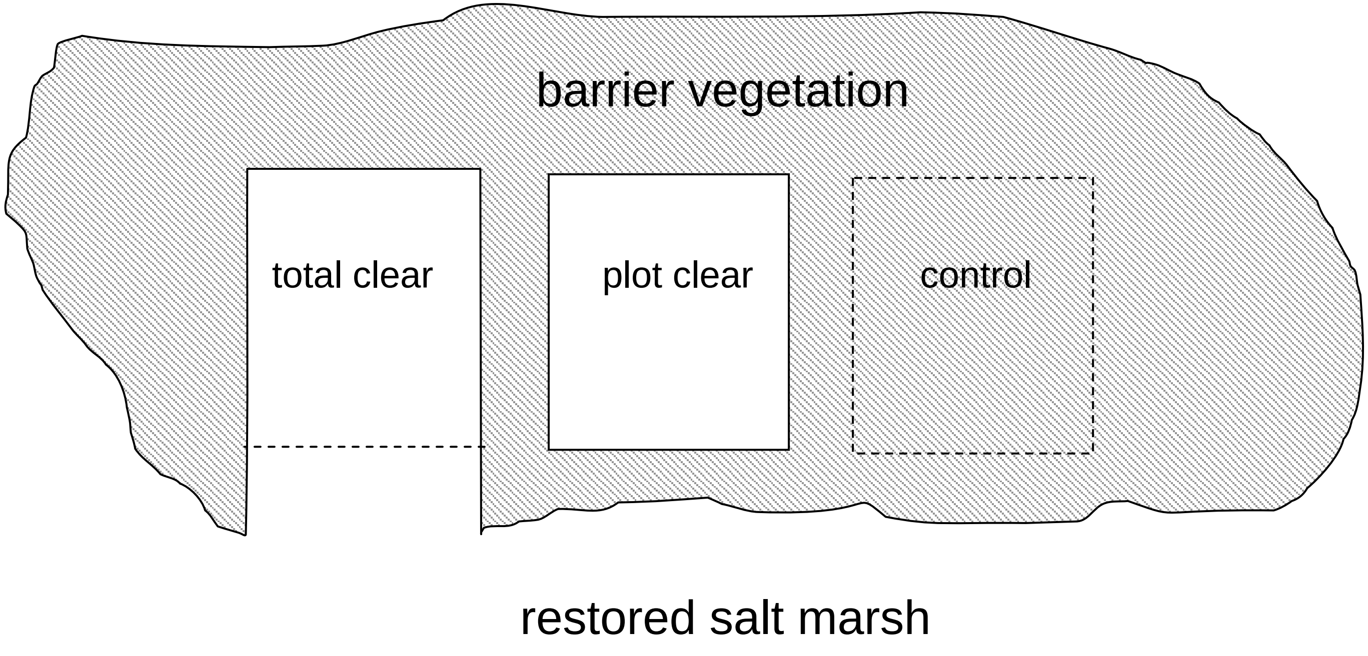
Vegetation clearing without any topographic “conduit” also enhances seawater penetration



Vegetation structure limits seed dispersal

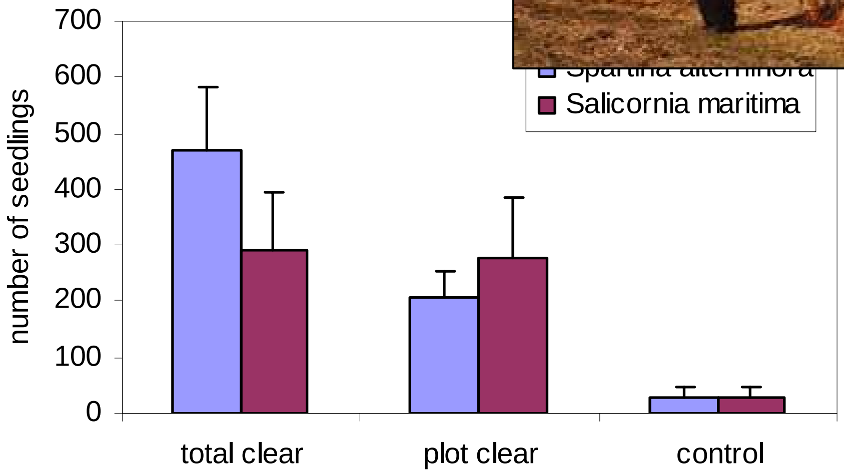
Removal of "barrier vegetation" to facilitate seed dispersal





Smith, S.M. 2007. Removal of salt-killed vegetation during tidal restoration of a New England salt marsh: effects on wrack movement and the establishment of native halophytes. Ecological Restoration 24: 268-273.

	Species	Pre-treatment TC	PC	C	Post-treatment TC		PC		C	
MEANS	*Spartina alterniflora*				)	a	172 (54)	a	26 (16)	b
	Salicornia maritima					a	228 (106)	a	24 (15)	b
	Salicornia virginica					a	0.2 (0.2)	a	0	a
	Suaeda maritima					a	0.4 (0.4)	a	0.4 (0.4)	a
	Limonium carolinianur					a	1.0 (0.63)	a	0.6 (0.6)	a
	Spartina patens (cove					a	0.2	a	0.6	a



Conclusions:

- Restoration increased the height of high tides while maintaining drainage and protecting the airport from Spring high tides (and storm surges)

- The decline of salt-intolerant taxa is rapid

- The expansion of native halophytes is much slower, quite variable among species, and their expansion is hindered by original, salt-killed vegetation

- The recovery of salt marsh plant communities during tidal restoration can have a strong spatial component that is related to elevation, salinity, and distance from the point of seawater entry into the tide-restricted system

- Incremental increases in tidal flow over a long period of time may not reduce the system-wide abundance of *Phragmites* because this species is able to migrate away from stressful growing conditions

- Artificial creeks and removal of vegetation enhance seawater penetration and seed dispersal

- Despite no further change in seawater exchange capacity, the vegetation and hydrology of the restricted marsh is still adjusting and changing and will do so for a long time to come

Thank you!